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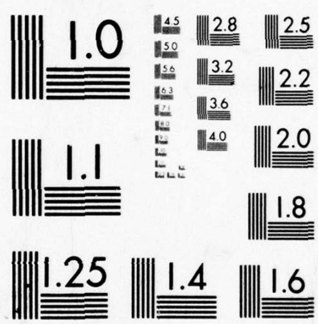

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OFFICE OF NAVAL RESEARCH

INTEGRATED APPLICATIONS OF AUTOMATED SPEECH TECHNOLOGY FINAL REPORT

BOEING AEROSPACE COMPANY
LOGISTICS SUPPORT AND SERVICES
SEATTLE, WASHINGTON 98124

CONTRACT N00014-77-C-0401
ONR TASK 213-158

14 FEBRUARY 1978

FINAL REPORT

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The work performed and results obtained during the conduct of the Integrated Aspects of Automated Speech Technology (AST) study contract are documented in this report. The report is intended to supplement the accompanying Program Plan in order to be of assistance in understanding the methodology and limitations of both this study program and the Program Plan document. Four of the major program tasks; AST Technical Review, Crew Station Design Application, Performance Measurement, and Training Applications are described. The technical

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20. Abstract

review includes the rationale behind automatic speech recognition applications, application programs, human factors aspects of AST, and a summary of the technology. Crew Station Design Applications cover the baseline mission selection, the P-3C baseline description, crew task analysis, applications rating process, and a subsystem versus generic tasks potential payoff matrices development process. Recommended AST applications are provided along with scheduling data.

PREFACE

This report documents the work conducted under the Office of Naval Research contract No. N00014-77-C-0401 between May 15, 1977 and February 14, 1978. This work was performed by the Logistics Support and Services Division of the Boeing Aerospace Company and the Tactical and Training Systems Division of Logicon, Inc., a subcontractor to Boeing for this program. The primary results of the Boeing/Logicon effort are contained in the Integrated Applications of Automated Speech Technology Program Plan.

The authors are indebted to the following persons for their guidance and contributions:

CDR Donald C. Hanson, Office of Naval Research, Technical Contract Monitor

CDR Patrick M. Curran, Naval Air Development Center

Within the Boeing Aerospace Company, the program was directed by Mr. W. J. Hebenstreit of the Crew Systems Organization. The Logicon effort was directed by Mr. L. D. Egan. Other Logicon personnel whose consultation during the program contributed significantly to the work described herein include: Mr. M. W. Grady and Mr. C. R. Durfee.

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this technical report is to document the work performed and the results obtained during the period of this contract. It is intended that this report be of considerable assistance to the users of the Integrated Applications of Automated Speech Technology Program Plan. It will assist them in their understanding of the methodology and limitations of both this study program and the aforementioned program plan for recommended test and evaluation of various automated speech technology (AST) applications/projects.

The objective of the study program, The Integrated Applications of Automated Speech Technology, was to develop a methodology for integrated applications of automated speech technology to both Navy operational and training situations.

1.2 Scope

The use of the term automated (or automatic) speech technology (AST) refers to both automatic speech recognition (ASR) and speech generation. This study program covers both aspects of AST. However, because ASR is the more difficult aspect of AST to accomplish, it has received more emphasis in this study program.

The study program was divided into essentially five tasks in order to accomplish the above indicated program objective. The first task was to establish a baseline of present day AST from which to proceed. The second through fourth tasks were to analyze and define appropriate tasks for application of AST to each of the three areas: a) crew station design, b) performance measurement, and c) training functions. The fifth and final task was to develop a long range test and development program plan for validation of the above listed applications concepts. The first four of these tasks are described in detail in Section 2.0 of this report. The scheduled accomplishment of these tasks in relation to the major program milestones is shown in the following section.

1.3 Program Schedule

The major portions of the program, including the previously described five tasks were accomplished over a seven month period beginning on May 15, 1977. This seven month effort was followed by a two month period for customer review of the program documentation and refinement as necessary. The submittal of the approved program plan and the final report was made on February 14, 1978. Figure 1.3-1 shows the program schedule of tasks and significant events as they actually occurred. Although an informal initial meeting was held in Orlando, Florida on May 3, 1977, to discuss the program, the official kickoff meeting occurred on May 26 after the contract start date. The meeting was held at Logicon, Inc., in San Diego, California. The purpose of the meeting was to review the proposed program schedule and to agree on the details of the tasks to be accomplished and the type of mission to be used as a baseline for such tasks. A significant additional topic of discussion at the kickoff meeting was the July 5-6, 1977 Apportionment Review and the need to present preliminary results from this program at that meeting. Following the kickoff meeting, and prior to the mid-term review, several informal meetings occurred between various Navy, Boeing, and Logicon personnel.

The Mid-Term Review took place at the Office of Naval Research in Arlington, Virginia on October 4, 1977. Program progress and plans for completion were presented by Boeing and Logicon. Outlines for the Program Plan and the Final Report were presented for review and comments.

The initiation of work on the five major program tasks occurred in a slightly different order than originally planned. As can be seen from the Figure 1.3-1 schedule, the Technology Review Task did not begin until approximately a month and a half after the start of the program. The reason for the delay in Task 1 was to concentrate the program efforts on Task 2, Crew Station Design. This task was started earlier than planned in order to provide preliminary data in support of AST and this program for the aforementioned Apportionment Review meeting. The accomplishment of the remaining three tasks occurred in the order originally planned.

PROGRAM SCHEDULE

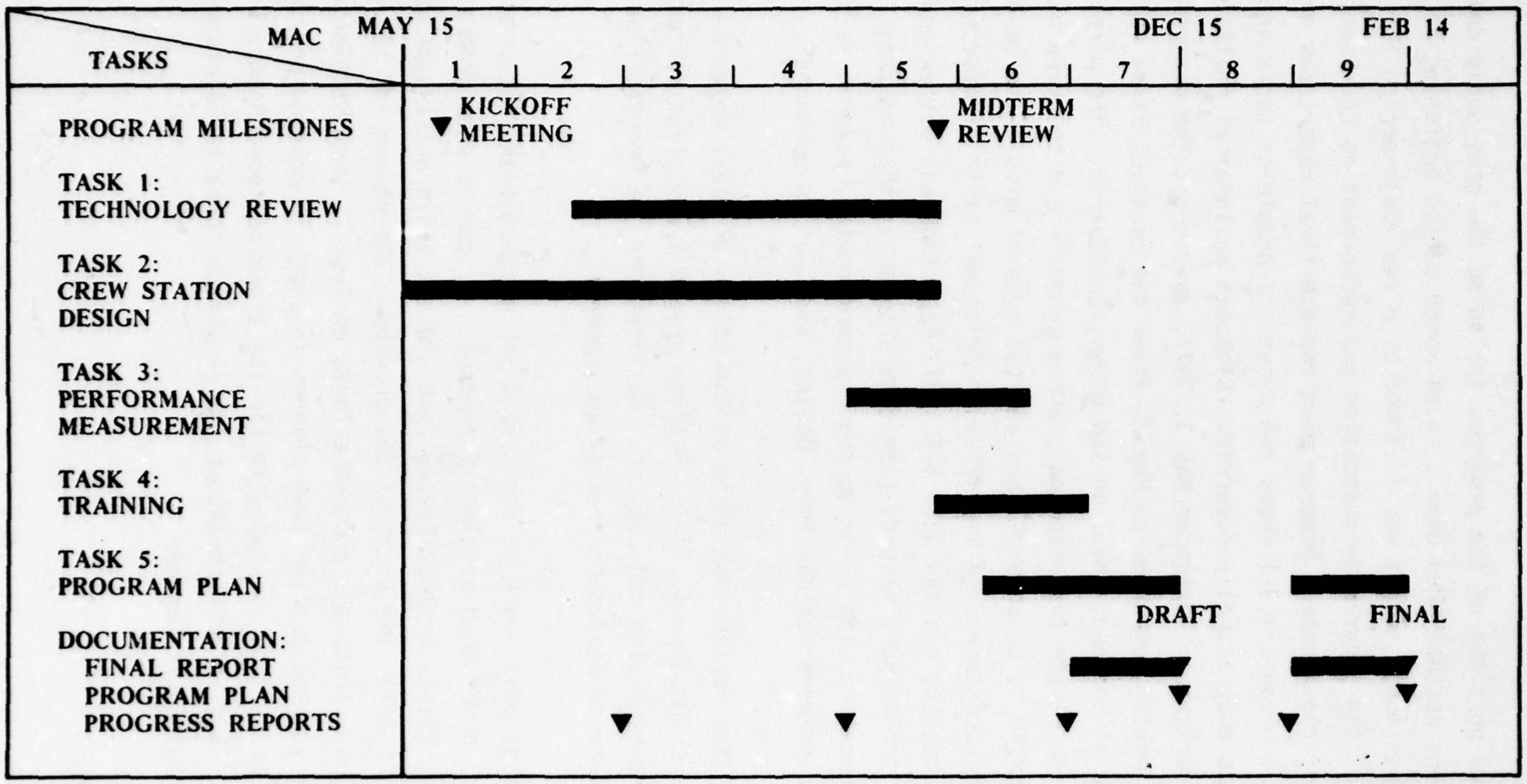

Figure 1.3-1, Program Schedule

In addition to the minutes of the Kickoff and Mid-Term Review meetings, the documentation for this program has consisted of four bi-monthly progress reports, preliminary drafts of both a program plan and a final report, and approved final versions of these same two documents.

2.0 TASKS ACCOMPLISHED

The following four sections describe the details of the work accomplished during this study program. Section 2.1 contains the complete results of the current technology review. Section 2.2 covers the task work performed in the analysis of AST application to crew station design. The additional applications of AST to both operator performance measurement and training are contained in Section 2.3. Section 2.4 describes the process used to compare each of the possible AST applications taken from crew station design, performance measurement and training. These applications are compared on the basis of feasibility, risk, cost, and impact in order to choose the most promising projects for inclusion in the program plan.

2.1 AST Technical Review

The following material was prepared as Task 1 of the study program. This task was performed and the results included herein in order to familiarize the users of the report and the program plan with the state-of-the-art in AST. These applications and their supporting data may be used as AST baseline information from which Navy managers can subsequently plan AST applications. Additional survey information as to the speech understanding field are now being conducted by Speech Communications Research Laboratory, Inc. However, these data will not be available for some time. Several presentations and publications, including two forthcoming books will report such work.

In this decade, the technology of AST and automatic speech recognition (ASR) in particular, has progressed from the status of an R&D topic to that of a viable alternative to conventional man/machine interface devices. While ASR progress has not met the goals established by Newell, et. al., (1971), for the ARPA Speech Understanding Research Program, it has encouraged application of ASR to various systems where vocabulary requirements are consistent with the capability of commercially-available, isolated word devices. As described by Beek, Newberg, and Hodge (1977), these applications serve government systems of various types. These include:

a. Training systems (and performance measurement).
b. Crew station systems on aircraft.
c. Command verification systems on ships.
d. Intelligence data handling.

In several of these applications, development has progressed to the point where demonstrations, experiments, and tests have been conducted on the system or subsystem level to verify the feasibility of AST as a data interface in man/machine systems.

2.1.1 Rationale Behind ASR Applications

To understand the impetus for ASR application, the human roles in large systems as they are presently configured must be examined as well as the assistance speech technology might offer to these roles. With the advent of modern, highly-sophisticated systems, the scope of man's involvement has burgeoned to a point where his performance shows signs of degradation as a result of work overload. Cockpit design, for example, has not kept pace with overall weapon system design. Dated, slow input devices still are being employed to enter data into the system. This requires the operator to share attention between several sources of information. Head-up displays (HUD) have been developed to deal with this problem but serve only as a partial solution.

What is needed is a new mode of inputting and outputting data into a system that:

a. Frees the hands and eyes for other tasks.
b. Does not disrupt attention.
c. Is faster than present modes.
d. Is equally (or more) accurate than present modes.

Further, the new mode must be compatible with environmental constraints and, above all, must be acceptable to the operator. ASR potentially offers these advantages. For example, Turn (1971) has indicated that speech is:

a. A natural channel for human communication.
b. Independent of the visual channel and motor activities.
c. Omni-directional (thus, no free line-of-sight is required).
d. Informative about the speaker.
e. Faster in data rate (not necessarily information rate) than other input modes.

These advantages of ASR suggest that it may be an extremely desirable input mode if a device can be constructed that: first, understands speech without requiring the human to alter his "natural" speech habits; second, has sufficiently high recognition accuracy to prevent user dissatisfaction; and third, is cost-effective.

This review will determine the extent to which present application programs show promise for ASR as an improved input-output method.

2.1.2 Application Programs

In conducting this review it was decided to concentrate on newer programs that have applied automated speech technology (AST) as part of a larger system. Older applications, such as baggage handling and inspection line systems, are well documented elsewhere and offer little in the way of state-of-the-art advancement for AST application. Similarly, research programs were not reviewed except where pertinent to specific application problems. In all of the cases reviewed, the identifcation and review of present and near-term future applications will allow Navy planners to track applications that might interest them. Thus, the purpose of the following paragraphs is to identify and to summarize the status of various AST applications as potential contributions to subsequent Navy AST planning and programming.

2.1.2.1 Operational Applications - During this AST review, a variety of programs were examined which attempt to apply AST to operational problems such as cockpit design, shipboard command verification, and paraplegic support. These applications have been supported by several government agencies including DOD, NASA, NEW and DOT. The technical effort has been supplied by laboratories within these government agencies and by several companies, including Logicon, Dialog Systems, Analytics, and Threshold Technology. These applications are reviewed by topic below.

The earliest application of AST to an operational military problem was performed at the Naval Air Development Center (NADC) Human Factors Laboratory. The program at NADC was initiated to determine the desirability of interactive voice systems for use in airborne weapon systems crew stations. To accomplish this effort, NADC developed a voice recognition and synthesis (VRAS) system which was incorporated into the centrifuge at NAS, Johnsville, Pa. The speech recognition aspect of VRAS was developed using a voice command system (VCS) which was developed by Scope Electronics. The speech synthesis capability was supplied by a Votrax VS-5 speech synthesis unit built by Vocal Interface. Development of the system was performed jointly by Scope and NADC personnel, notably R. Wherry, Jr.

The effects of flight on automatic speech recognition was determined by using three subjects (two pilots and one psychologist) who were given repeated trials in the VRAS-equipped centrifuge to determine the effects of vibration, G, O_2 mask, mission duration, and cockpit temperature on voice quality. The results showed that:

a. Voice quality degrades after 0.5 hours with an O_2 mask.

b. Voice quality degrades under high (± 3G) vibration.

c. Voice quality degrades under higher levels of G.

These results were obtained with a baseline of 80 percent recognition accuracy with the VCS.

The next phase of the NADC program called for improvements of the VCS system. This was accomplished in two ways.

a. A consistency bit was incorporated into the process wherein reference patterns are established to improve recognition accuracy. Improved recognition accuracy was noted.

b. A syntactic handler was developed to facilitate human usage of the isolated word VRAS system and simultaneously assist in the understanding process.

The syntactic handler was tested with teletype input and was operational with 100 percent accuracy in real time. It presently is being translated into FORTRAN IV (by Wherry) under contract to Analytics, Inc. Translation should be complete within the next few months thereby allowing its use on a variety of computers rather than solely on the Raytheon 704. Since the syntactic handler only requires a recognized word or phrase as input, it can be used with a VIP-100 or any other recognition device as well as a VCS. Wherry estimates it would take between one and four weeks to develop a syntactical handler for another application.

The power of the syntactic handler is that it will allow the user to vary the syntactical arrangement of words during data entry without affecting recognition accuracy. Thus, the natural quality of speech as a data entry means is preserved.

An informal attempt to incorporate VRAS into the LAMPS simulator at NAS, Johnsville was made in 1975 but interface problems between the simulator computer and the Raytheon 704 in the VRAS system prevented any formal operability demonstration.

Crew Station Design - NASA. A second application study is being conducted at the NASA Ames Laboratory in California. At NASA Ames, feasibility of speech recognition as an input means for a flight management system in commercial aircraft (including helicopters) is being investigated. NASA's program assumes that large digital computers will be placed on-board the aircraft; NASA's task is to utilize these computers for maximum benefit. As a facilitation of the computers, speech input is thought to offer several advantages to human operators, including freeing of hands and some degree of attention.

Beginning in 1972, NASA Ames purchased a Scope VCS recognition device (which was the only device commercially available then). Faced with poor recognition accuracy, even with a 10 word vocabulary, NASA Ames opted to improve recognition accuracy before pursuing device application. By structuring their vocabulary and using a single detection approach to recognition, recognition

accuracy for a 100 word vocabulary is now 98 percent without rejection and almost 100 percent with a 5 percent rejection rate. These figures are sufficient to warrant progression to experimentation.

The experimental phase, which began in January, 1977, will compare speech entry to keyboard entry for mixed tracking tasks. Speed and accuracy of input will be measured as well as tracking accuracy. Subsequent experiments will involve identification of background noise, vibration, and motion factors.

After initial experimentation, the next step will be to chain keyboard and speech entries in a meaningful navigation/guidance context to compare performance on a visual/manual tracking task in a high-workload situation.

The overall goal of the program is to introduce a voice operated system into actual flight conditions for evaluation purposes. With this intention, discussions and demonstrations with P-3C TACCOS have been conducted with favorable results. A ruggedized computer (Rolm) also has been purchased with this application in mind.

2.1.2.2 Training Applications. As part of this technological review, two applications of AST to training were identified. Both applications concerned military training and both were conducted by Logicon, Inc. (under contract to Naval Training Equipment Center, Orlando, Florida). In addition, these applications involved both speech synthesis and speech recognition aspects of AST.

The initial application of AST to training was conducted as part of the Adaptive Flight Training System (AFTS) program. The following application concerned the use of AST to train ground-controlled approach (GCA) controllers in a synthetic environment. The latter application is called CGA Controller Training System (GCA-CTS). These applications will be discussed within the ensuing sections.

AFTS. The initial application of AST to training problems began as a result of a requirement in Logicon's AFTS program for a "synthetic" GCA controller to replace live "pseudopilots" in simulated GCA training of aircrews. Speech generation thus became the link between the automatic controller and student aircrews on simulated GCA exercises.

In the 1969-1973 era, a voice drum was the only technology available for computer-controlled voice simulation. This approach used specially produced tapes on which all words within the vocabulary were recorded, in short equal length intervals (often one second in length). The user's vocabulary, such as GCA phrases, then was constructed by combining several of the recorded words into one phrase, under computer control.

The result of combining equal length words in a phrase was an unnatural, choppy, but intelligible string of sounds that were marginally adequate for simulation purposes. This approach, supplied by Cognitronics or Metrolab, was used in the early feasibility demonstration versions of AFTS with reasonable success.

By 1974, several digital voice synthesizers were available on the commercial market. Logicon chose the Votrax unit (made by the Vocal Interface Division of the Federal Screw Works) as the replacement for the voice drum. This new approach, which synthesized artificial phoneme-like sounds into words, not only sounded more natural but cost far less than the voice drum approach.

The AFTS, with the improved Votrax VS-6 speech synthesis unit, was installed at Luke AFB in 1974 as an "add-on" to the F-4E Weapon System simulator (A/F 37U-T9). AFTS' initial purpose was to train aircrews in GCA phases of operational F-4 missions. During 1975, the scope of AFTS was increased to include air-to-air intercept and ground-attack radar phases of F-4 simulator training. To add automation to these additional mission phases, Logicon incorporated automated speech recognition (ASR) systems which understand important tactical messages (such as those contained in the operational brevity code) spoken by the aircrew to ground

controllers. To determine the feasibility of performing this function, a Threshold 500 speech processor and Logicon-developed software were installed in AFTS to capture approximately 24 key messages (such as JUDY, CONTACT, etc.) spoken by the pilot and the weapon systems officer.

Combined with the already existing speech synthesis capability, the enhanced AFTS provides an interactive system in which aircrew messages are automatically understood and responded to with the appropriate synthesized voice outputs. The following is an example of the AFTS-to-aircrew dialogue:

AFTS:	"Phanton 1, cleared for reattack"
Aircrew:	"Say again"
AFTS:	"Phantom 1, cleared for reattack"
Aircrew:	"Roger"
AFTS:	"Phanton 1, Contact"
Aircrew:	"Roger, contact is target"
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Aircrew:	"Phantom 1, Judy"
AFTS:	"Roger, Judy"
Aircrew:	"Phantom 1, Lost Contact"
AFTS:	"Phantom 1, you have a target at 258"
Aircrew:	"Phantom 1, Roger"

With the vocabulary of 24 items shared between two users, recognition accuracy in AFTS was observed to be lower than other applications (~ 80-90 percent). The lower accuracy stems from several problems that might affect any application outside a controlled environment.

These problems are:

a. Noise. A 400 Hz noise source in the simulator's intercom system masks the lower frequency of voice transmission.

b. User acceptance. Because the enhanced AFTS has not been fully integrated into the simulator syllabus, the aircrews have not been diligent in maintaining their voice file (or training file) for voice understanding.

c. Training-using fidelity. The system does not require the using aircrews to "train" the speech recognition system in a mission context. Training is done off-line by simply repeating a given phrase 10 times. However necessary, this process has been reported as "boring" by users. Further, the F-4E syllabus does not require crew members to adhere to a rigid vocabulary; therefore, the training process is frequently ignored. This leads to low fidelity between the messages trained and used which, in turn, effects recognition accuracy. (For maximal recognition accuracy, fidelity should be high, if not perfect.)

It should be noted that these problems are the results of the "feasibility study" status of the enhanced AFTS. They do demonstrate, however, the necessity of dealing with device training as a variable that can affect user acceptance.

GCA-CTS. As a result of investigations into speech synthesis for AFTS, Logicon became aware of ASR and its potential for training skills which are primarily verbal. One such application is in the air traffic control environment where controllers are taught the use of specific short phrases to direct the ground controlled approach (GCA) of an aircraft. Specifically, ASR offered an opportunity to automate both instructor functions (e.g., performance measurement) and pseudopilot functions (e.g., simulation of pilot's responses to the advisories and environment) during simulated GCA practice. Objective measures of controller performance during GCA runs were also provided.

In 1973, feasibility studies were conducted by Logicon for NAVTRAEQUIPCEN that demonstrated that sufficient ASR technology existed to make GCA controller training possible (Feuge and Charles, 1973). A laboratory demonstration version of a GCA controller training system (GCA-CTS) was developed which used a vocabulary of 45 GCA phrases, with each phrase composed of up to eight words whose length approached 2-3 seconds. Operating in real-time,

the GCA-CTS used a VIP-100 made by Threshold Technology, Inc. Recognition accuracy was observed to range about 95 percent with trained speakers.

The first system delivery of the GCA-CTS to NAVTRAEQUIPCEN in 1974 represented the initial application of ASR to a sophisticated training problem. Unlike the AFTS, the entire automatic training concept (objective performance measurement and adaptive syllabus control) is contingent on the efficacy of the speech technology components of the system.

Several advancements to the state-of-the-art in ASR were developed for the GCA-CTS application; these included:

a. Long phrases (2-3 seconds) which were recognized with high accuracy. Individual words (or sometimes 2 or 3 word phrases) previously limited the vocabulary.

b. A larger vocabulary (45 phrases) which was easily accommodated. Previous applications used a maximum of 32 words.

c. Software which was enhanced to accommodate rapid-fire voicing with less than a half-second between vocabulary phrases.

d. A digit extraction algorithm which was developed and used for high accuracy recognition of the final digit from a long phrase.

e. Effective schemes which were developed for distinguishing small differences between vocabulary phrases.

f. Level of confidence which was effectively used in the recognition process to distinguish between student and machine recognition errors.

g. The speech recognition subsystem which was packaged as a highly flexible set of FORTRAN routines which thereby enabled the easy modification of vocabulary and application.

Subsequent developments of the GCA-CTS incorporated speech generation capabilities have provided improvements in the training methodology. Thus, the GCA-CTS demonstrates the integration of the speech technologies into one complete system. The limitations of the recognition technology (e.g., requirements for a priori training data) should present no difficulty in GCA-CTS because they are incorporated into the overall training program by having the student learn the vocabulary at the same time that the computer is developing reference data. The verbal behavior of the student is critical to his task, therefore, he is expected to be a willing and cooperative participant. The small number of unnatural speech stylizations have been accepted readily and generally learned easily.

At present, the GCA-CTS resides at the NAVTRAEQUIPCEN Human Factors Laboratory as a laboratory demonstration model for further development. While at NAVTRAEQUIPCEN, the GCA-CTS has been reviewed by training personnel from NATTC as well as Fleet controllers. These reviews, which have been largely favorable, have led to further refinement by NAVTRAEQUIPCEN, particularly in the training conceptualization of GCA controller training. The GCA-CTS studies at NAVTRAEQUIPCEN (Breaux and Goldstein, 1975) have shown that:

a. Recognition accuracy increases as user experience with ASR increases (speech variability is reduced).

b. Recognition accuracy is an inverted "U" function of controller experience (confidence in controlling).

c. Recognition accuracy varies as a function of the type of vocabulary (some vocabularies contain items which are inherently similar to one another).

These results indicate that considerable skill must be used in applying ASR. An approach must be developed to reduce speech variability and account for highly similar vocabulary items if recognition accuracy (and, hence, user acceptance) is to be maximized.

Shipboard Automatic Command and Response Verification (ACRV). **The ACRV application study was conducted by Logicon for the Department of Transportation in 1976. Its purpose was to test the feasibility of a system where orders from the conning officer of a ship could be automatically monitored, compared to the helmsman's response, and verbally indicated and sent back to the conning officer if an error in the helmsman's response were suspected. Automation of the command verification system was achieved through the use of a Threshold Technology VIP-100 (for speech recognition) and a Votrax VS-6 speech synthesis unit, which were combined in a mockup of a Coast Guard cutter bridge at Logicon's computer center.**

Demonstrations of ACRV to DOT and Coast Guard personnel have proven the feasibility of ASR for command and response verification tasks. These demonstration tests indicated that speakers with little or no prior experience with AST averaged 93.3 percent recognition accuracy after three hours of practice with a vocabulary of 63 phrases. Speakers with lengthy AST experience consistently averaged over 98 percent recognition.

From the AST point of view, the command verification system offered several design challenges; i.e., it used a large vocabulary (64 phrases), very similar phrases ("starboard ahead 1/2" vs. "starboard ahead 2/3"), and considerable speech stylization ("indicate..1..1..0...revolutions"). Moreover, the design of the automated advisories was critical in the decision of what, when, and how the computer should respond to a detected error.

The recognition software developed for the ACRV system was very similar to that of Logicon's GCA-CTS. To minimize core requirements, all the referenced patterns were stored on disk and selectively retrieved in real time when they were needed. Using this scheme, the vocabulary size was limited only by practical considerations such as "training time" etc. The ACRV scheme would be particularly useful in a structured vocabulary (such as those used by NASA Ames) since the amount of data which must be retrieved from mass storage would be further limited.

2.1.2.3 Hospital Systems. Another type of application is being developed by Dialog Systems, Inc. It seeks to apply ASR to aid paraplegic patients in large hospitals such as the VA Hospital in Roxbury, Massachusetts. The hospital application will have a 105 word vocabulary, composed of discrete words or phrases which will be separated by a 0.25 second pause. The system is designed to allow paraplegic patients to perform the following functions by voice:

a. Type on a typewriter.
b. Dial a telephone.
c. Answer a telephone.
d. Change TV channels.
e. Control room lighting.
f. Operate bed motors.
g. Operate a desk calculator.

The vocabulary is syntactically structured much like those on the NASA Ames and VRAS systems. Estimated recognition accuracy ranges from 96 percent to 99+ percent, depending upon speaker training. The system will be largely speaker independent, using reference patterns derived from the "Greek chorus" of 50 speakers for each specific vocabulary item. For individuals who observe low recognition accuracy, a short training period (consisting of six repetitions of key words) will be used to individualize the "chorus" and thus improve accuracy.

The Dialog Systems' "front end" uses 32 frequency channels and a comb filter to produce data that are processed in search of the first two formats. Time is normalized. The pre-processor is composed of 11 to 14 boards. Dialog Systems uses a PDP-11/04 and 232K of memory (MCS) to achieve a near real-time recognition capability. Response time is estimated to be 50 milliseconds (essentially real time) for a 100 word vocabulary. Their system, at present, weighs 600 pounds and is rather bulky. In subsequent applications, Dialog is planning to reduce their system to 250

pounds and a volume of from 1.0 to 1.5 cubic feet. Cost ranges from $40,000 to $60,000 for a turnkey system. Their voice output is through a Cognitronics 31 system.

Dialog has performed no user-oriented studies. As their representative indicates, their application (hospital environment control) cannot be accomplished by the patient independent of other people; thus, it is bound to be acceptable.

2.1.2.4 Application-Oriented Research and Development. In addition to the preceding described application, an application-oriented research problem is being conducted by Logicon for NAVTRAEQUIPCEN. The research is aimed at the development of a limited continuous speech recognition capability which could be used to understand (in real time) long strings of digits, spoken rapidly without pausing between digits.

Logicon's approach is to use a standard VIP-100 preprocessor, minicomputer, and special software. This approach emphasizes the latest trends in current speech research, namely:

a. Treating the speech preprocessor as a sound classifier rather than as a phoneme detector.

b. Emphasizing the derivation of the recognizable speech characteristics from real speech data.

c. Decoding the speech signal sequentially rather than by exhaustive hypothesis and test methods.

Continuous speech, it is postulated, can be characterized and recognized on the basis of observing:

a. Characteristic classes of output from a preprocessor.
b. The order in which these occur.
c. The characteristic time durations between the output samples.

Higher knowledge sources, such as semantics, are seen as irrelevant to the recognition process for the chosen vocabulary.

If proven feasible, limited continuous speech recognition would perhaps solve problems that plague isolated word systems, such as recognition of key words or phrases that are imbedded in a larger utterance. For example, recognition of the specific heading in the GCA advisory "Heading is 289" would be possible without speaker stylization or vocabulary stylization which is required today. The feasibility of such an approach to limited continuous speech recognition will be tested late in 1977.

In another line of research and development, an alternative speech recognition device is being developed by Centigram, Inc., which will be capable of recognizing a limited set of 16 digits and other words in real time. Centigram's device is projected to be significantly less expensive than other devices in the commercial market (approximately $3,000) but its accuracy must still be proven before application can be seriously considered.

2.1.3 Human Factors Aspects of AST

As described by Turn (1971), AST should provide an exceptional input/output channel for humans because it is natural, fast, and accurate. However, little empirical evidence is available to indicate how AST compares to conventional input and output devices concerning dimensions such as speed, accuracy, and user acceptance. To resolve the problem, Rome Air Development Center funded Threshold Technology in 1977 to conduct a series of studies designed to shed empirical light on the subject.

The following paragraphs present information obtained from a preliminary, unapproved copy of Threshold Technology's final report.

Threshold Technology conducted two data entry experiments (Welch, 1977) which varied the type of task, data entry device, feedback, and degree of hand

occupation. Using 48 volunteers with varying experience with keyboard, voice, and Graf pen entry devices, Threshold obtained results which indicated that:

a. For simple tasks requiring an individual to copy numeric data rapidly, keyboard entry was significantly faster and more accurate than voice. For alphanumeric data entry, keyboard entry was faster but less accurate than voice entry.

b. For complex tasks requiring cognitive and visual effort, voice entry provided higher throughput then keyboard entry, particularly with inexperienced personnel, because of its ability to free the eyes.

c. Voiced feedback (provided by a speech synthesis unit) slowed voice entry because most subjects waited for the verbal feedback to cease before entering additional data.

d. The requirement to correct initial recognition errors by voice frequently led to additional errors which further reduced speed of response.

e. Voice data entry was faster than other entry modes when the hands were occupied for a substantial portion of the total entry time.

f. Combining verbal feedback (or prompting) with visual feedback (or prompting) did not facilitate speed or accuracy of entry.

Summing up these results, it is concluded that with present isolated-word ASR equipment (which requires pauses between entries and which has a 2-3 percent error rate on recognition) ASR is not clearly the faster or more accurate data entry device. Rather, the advantages of voice entry are limited to certain types of tasks, to inexperienced operators, or to situations where hands or eyes are not free for other forms of entry. Under the pressure of a high speed entry task, the correction of errors made during initial voice entry often led to more errors which was observed to "rattle" the subjects.

This result does not support ASR over present crew station entry methods, particularly in combat or other pressure-inducing situations. As pointed out by Threshold, a combination of entry devices is likely to meet all the requirements for each specific task. This will require human factors studies and trade-offs to optimize overall data entry design. These generalizations are limited to the condition of Threshold Technology's studies and should be reexamined with tasks more relevant to aircrew duties.

2.1.4 Technology Summary

The purpose of this summary is to assess the status of successful application of automatic speech recognition. To accomplish this, it seems useful to review all of the advancements described in the review of applications (Section 3.0) and speculate about what their combination might be capable of producing. For this conclusion, the following dimensions of AST reflect present capabilities as verified by demonstration or test:

a. Type of Speech. For the present (and probably at least the next five years), applications will be confined to the use of isolated word devices where the vocabulary is predefined, rigorously adhered to by users, and composed of discrete words or phrases separated by short (0.25 second) pauses. The development of limited continuous speech recognition (LCSR) may liberalize these conditions, allowing perhaps different syntactical arrangements of key words and eliminating the requirement for pauses between words. LCSR, however, will still require a predefined vocabulary.

b. Vocabulary. At the present, isolated word devices are limited to approximately 100 utterances without reducing recognition accuracy. For certain applications, the vocabulary can be constructed to handle a much larger number of items (perhaps 500) with good recognition accuracy accomplished by ordering and by sequencing

voice entries according to syntactical rules for data entry (e.g., system identification - switch identification - value or setting). Wherry's syntactical handler for the VRAS not only will allow expansion of the vocabulary but will allow greater flexibility on the user's part by allowing different syntactical strings to be semantically equivalent.

c. Recognition. At the present, isolated word devices are capable of 95+ percent recognition accuracy with a vocabulary of 100 items. However, recognition accuracy alone can be a misleading figure because the false alarm rate must also be taken into account. Extremely high recognition accuracy can be obtained if one is willing to suffer a high false alarm rate and/or a high rejection rate. In many cases, however, a false alarm or a rejection is as harmful to system goals as an error (which is to say lower recognition accuracy).

d. User Acceptance. At present, most applications require the user to train (or tune) the system on his voice characteristics. This process of training the system serves two purposes:

1. It creates reference data for subsequent recognition process, and

2. It trains the user on the syntactical requirements of the vocabulary.

To be most useful for the first purpose, the device should be trained so that the user pronounces each vocabulary item as if he were actually using it (i.e., with appropriate voice inflection, etc.) in the system context. This procedure will produce greater fidelity between training and use, and thereby facilitating recognition accuracy.

Developments such as Wherry's syntactic handler, and Dialog System's speaker independent system (although untried in application) offer promise for improving user acceptance of AST. Without user acceptance based on actual beneficial performance, AST is just another new technology.

The combination of new developments contributed by NADC, NASA Ames, Logicon, Dialog Systems, and other agencies provides a powerful new technology for man/machine interface designers. With careful planning, these various advancements can be used to make man's communication with machine natural and efficient.

2.2 Application to Selected Crew Station Design

It was anticipated that a large number of AST applications and requirements could be found through the detailed analysis of a typical crew station design. Advanced research and development activities in the areas of cockpit and crew station design had already demonstrated the technical feasibility of utilizing AST to assist aircrews in their operational duties (e.g., VRAS). Speech technology could provide additional modes for information transmission and could thereby unburden the operator during periods of peak workload by exploiting his basic propensity for hearing and speaking while engaged in visual or psychomotor activities.

The fundamental approach to this task was to first choose a typical crew station system to use as a baseline from which to gather actual crew task data. The next steps were to obtain, analyze, and rate the task data for potential applicability to AST payoff. Matrices were then developed of these tasks versus the particular crew stations and subsystems with which the tasks were associated.

2.2.1 Baseline Mission Selection

Because the task of analyzing all available aircraft crewstations for possible AST applications was obviously impossible, it was proposed that only a limited

number be examined in sufficient detail to determine applications. The selection of a single crew station model or baseline system was made at the program Kickoff Meeting. The P-3C Antisubmarine Warfare (ASW) aircraft was chosen on the basis of:

a. The wide variety of operator tasks associated with all of the operator workstations aboard the P-3C.

b. The high probability that the P-3C will still be in the operational inventory when many AST applications are developed to the point of requiring operational evaluation. This factor is of benefit in two ways:

   1. Baseline data without AST will still be easily available, and

   2. The same P-3C subsystems/components may be used for testing and comparison throughout the evolution of the AST applications project.

c. There is at present a large amount of P-3C operator task data which is relatively available. These data consist of:

   1. The NATOPS manuals for each of the crew positions (NAVAIR 01-75PAC-1.X series),

   2. Courseware, Incorporated volumes (entitled "Job Analysis Document") for each of the more significant crew positions,

   3. Direct interviews with P-3C operators, and

   4. The P-3C simulation system (as well as other P-3C support operations) at NADC and other facilities.

d. All other systems examined had either too few operator stations or were scheduled to be available too far in the future to have any available data for comparison at this time (e.g., VPX).

The use of the P-3C baseline was limited to an examination of only the on-station portion of the mission. This limit had to be made because of program time and manhour availability. It should be noted that AST applications, which may be unique to other mission segments, were not examined in this study program.

For example, a major crew task procedure during the preflight portion of the mission is the performance of various checklists. This procedure would lend itself extremely well to the application of AST; however, it was not considered as a part of this program due to the mission on-station limit for crew task analysis. A further limit to the P-3C baseline was in the number of crew stations analyzed. Only the most significant crew stations were included. These crew stations were:

a. Pilot/Copilot,

b. Tactical Coordinator (TACCO),

c. Navigation/Communications Officer (NAV/COMM),

d. Sensor Station Operators 1 and 2 (SS-1, SS-2), and

e. Sensor Station Operator 3 (SS-3).

Although other crew stations, namely the Ordnance Station, Technician Station and Flight Engineer could have been analyzed, the time and budget available would not allow this effort in comparison to the other program tasks.

2.2.2 P-3C Baseline Description

The following description of the P-3C aircraft and mission may be of assistance in understanding the AST applications selection process.

The P-3C is a four-engine, low-wing aircraft designed for patrol and anti-submarine warfare. Distinguishing features of the airplane include advanced submarine detection gear including computer interfacing of the detection gear, the ordnance system,and the armament systems. The model is readily identified by the camera installed in the lower section of the forward radome, the installation of sonobuoy chutes, visible in the lower aft fuselage of the airplane and three additional small windows on the right side of the fuselage. Provisions are installed for carrying a streamlined low-light-level television camera pylon and pod on a wing station. Also provisions for carrying a streamlined ECM pod-pylon assembly are installed on a wing station.

The primary mission of the P-3C aircraft is detection, localization, surveillance, and attack of targets that pose potential military threat. Satisfactory pursuit of this mission is realized through the two phases of contact

development and contact refinement. Each crewmember plays a vital role in support of this mission, and the P-3C aircraft is designed and built to be operated as an integrated team effort.

The tactical coordinator (TACCO) is responsible for the tactical portion of the flight mission and will coordinate the functions of the entire flight crew. The pilot, as aircraft commander, is responsible for the flight crew being in their assigned positions for takeoff and landing, including ditching in an emergency. Each crewmember has individual responsibilities and duties as described in the following sections. Additional duties and responsibilities are assigned by the pilot and TACCO as necessary.

Each crewmember shall possess a thorough knowledge of the equipment at his station, plus a familiarity with equipment used by other crewmen, so that he can assume other duties in an emergency and facilitate normal crew coordination. Each crewmember is expected to be thoroughly familiar with safety and survival equipment in the aircraft and to be completely knowledgeable in the use and wearing of his personal equipment.

2.2.3 Crew Task Analysis

The next step in the crew station design task was to obtain P-3C crew task data. Much of these data were available in the NATOPS manuals (series NAVAIR 01-75PAC-1.X). The manuals were examined and found to be useful in providing data as to the very general task duties of each crewman. They were also excellent at providing the details of several frequently used crew procedures. The following position descriptions were taken from the NATOPS manuals:

a. Pilot/Copilot. When the pilot is assigned the duties of mission commander, he shall be responsible for all phases of the assigned mission. He shall direct a coordinated plan of action and shall be responsible for the effectiveness of the flight. He shall be

responsible for the crew preparation for takeoff, and for takeoff at the scheduled time. He shall gather and evaluate reports on the aircraft and equipment and direct preparation for flight as necessary. Further, the pilot acting as mission commander shall sanction armament selection and release.

As the patrol plane commander, the pilot is responsible for the effectiveness of the aircraft and crew for all matters affecting safety of flight. Prior to starting engines, before taxi, before takeoff, and at other scheduled times in flight, he shall call for the appropriate checklist to be read by the copilot, and shall respond as necessary. As aircraft commander, he shall coordinate ASW tactics with the TACCO and fly the aircraft as directed by the flight director indicator/horizontal situation indicator and tactical situation display in the prosecution of the mission problem. The pilot will stabilize the tactical plot via the on-top function. He will evaluate the tactical plot and coordinate with the TACCO the updating of the plot. The pilot will also enter visual contact data into the computer in support of the mission.

The copilot shall assist the pilot in preparing the crew for flight and in ascertaining readiness for flight of the aircraft and aircraft systems. He shall read the checklist, as required by the flight mission. He will pilot the aircraft at all times the pilot is away from his station. The copilot function is specifically patterned as a safety back-up for the pilot throughout the entire flight. In this capacity he shall offer constructive comments and recommendations as necessary throughout the mission in order to maintain the safest possible and most effective flight environment. The copilot shall call out all altitudes, airspeeds, and angles of bank as directed by the pilot, or the minimum safe altitude/airspeed for the mission. He may also be required to release stores, read checklists, operate the cameras, provide ship rigging information to the TACCO or NAV/COMM for computer entry and any other duties

as directed by the pilot. During the times the copilot is in control of the aircraft, his coordination of crew duties shall be the same as for the pilot.

b. TACCO. The TACCO's function is to employ appropriate tactics and procedures to most effectively carry out the mission of the aircraft and its crew. He will initiate a coordinated plan of action for all tactical crewmembers and continuously monitor, review and revise the plan as the situation dictates. He will make decisions regarding search and kill, stores selection and release. He shall ensure the accurate completion, collection and disposition of required magnetic tapes, logs and records.

The deployment of search stores is determined by the TACCO, and is normally accomplished by the computer. The ordnanceman, when directed by either the TACCO or the PILOT, may select and launch a store either manually from a pre-loaded SLT (sonobuoy launch tube) or PSLT (pressurized sonobuoy launch tube) or in the event of complete equipment malfunctions, through the free fall chute. Kill stores are selected in conjunction with the pilot by the TACCO.

The TACCO shall coordinate the efforts of all tactical crewmembers advising of the possibility of contact as well as informing them of surface traffic, and the spatial sonobuoy distributions. The TACCO will ensure that the proper EMCON (emission control) condition is maintained.

c. NAV/COMM. It is the responsibility of the navigation/communications officer (NAV/COMM) to maintain an accurate record of present and past positions, to insert navigation fly-to-points, update geographical position, transmit tactical messages as authorized for release by the aircraft commander, set up radio equipment before flight,

and maintain a record of the flight. The NAV/COMM is responsible for navigating the aircraft to the specified operational area and transmitting aircraft position reports in accordance with directives promulgated by the operational commander. The NAV/COMM shall provide data link assistance as directed by the TACCO. The NAV/COMM shall also monitor navigation systems in use. The TACCO shall be advised of navigation system failures.

d. Sensor 1 and 2. It is the responsibility of the acoustic sensor operators (SS-1 and SS-2) to detect and classify contact data. The audio information is recorded for subsequent mission reconstruction. The determination of sono target evaluation will be in close concert with TACCO for the determination of buoy types, RF's, target signatures, surface traffic, and the aggregate ASW environment.

e. Sensor 3. The Sensor Station 3 (SS-3) operator's function is to determine the position of a submarine by detecting changes in earth's Magnetic Field caused by the submarine's hull, to detect and analyze targets of military significance and provide radar intercept and navigation information to the Plane Commander. He also will challenge the identity of these targets. In addition, the Sensor Station 3 operator will passively detect targets of military significance using Low Light Level Television (LLLTV) and ECM (electronic counter measures).

During magnetic and submarine anomaly detection (MAD and SAD), the TACCO/PILOT notifies the SS-3 operator that the airplane is approaching the possible target location. The SS-3 operator will announce the presence of targets in the area as directed by the ECM/LLLTV equipment. The SS-3 operator will announce bearing and range of targets orally and/or by the keyboard functions, detected by search radar set and challenged by radar recognition set. The TACCO will specify the operational employment of the radar and challenging by radar recognition set. (EMCON)

In order to properly analyze operator tasks, data were needed as to the sequence, frequency, and criticality of the on-station crew procedures. Very little of this type of information was provided in the NATOPS manuals. Fortunately, this information had just been obtained and documented in several volumes by Courseware, Incorporated for the Instructional System Development (ISD) Team. This team was formed to develop training courses for the Readiness Training Squadrons VP-30 at N.A.S., Jacksonville, Florida and VP-31 at N.A.S., Moffett Field, California. Courseware obtained these data from Navy training experts who used existing documentation and review by their colleagues. Courseware then conducted a survey to gather data from approximately two dozen crewmen for each of the P-3C crew positions. These data consisted of the crewmen's opinions as to how relevant, critical, frequent, and difficult each of the mission tasks was. The information as to criticality and frequency was particularly useful to this study program. These ratings, which were provided for the purpose of ISD, were of invaluable use to the prioritization of crew station tasks in relation to AST applications.

The next subtask to be performed for the crew station analysis was to obtain sufficiently detailed task data to correlate to potential AST application. The Courseware data was generally one level of detail too high or too gross to be useful. The level of detail needed had to be obtained from the NATOPS manuals and Boeing and Navy personnel who had direct experience with the P-3C crew tasks. Interviews were conducted with these persons for the purpose of filling in and adding to the Courseware document task lists. In addition to the Boeing personnel interviews, numerous Moffett Field personnel were interviewed as to their opinions and experience in relation to crew tasks. To a limited extent, the Moffett Field simulator/training hardware was also examined as was the actual P-3C aircraft.

Detailed task list worksheets such as that shown in Figure 2.2-1 were constructed for each of the crewstations analyzed. The most tasks analyzed, approximately 320, were for the pilot/copilot workstation.

POSITION: P-3C PILOT

DETAILED TASK RATINGS

MISSION SEGMENT: ON STATION

	TASK	CRITICALITY H	CRITICALITY M	CRITICALITY L	FREQUENCY H	FREQUENCY M	FREQUENCY L	SUBSYSTEMS GEN TASKS
7.1.8.4	– PROP GOES THROUGH FEATHERED POSITION AND TURNS BACKWARDS – PUSH SHUTDOWN HANDLE IN – PULL FEATHER BUTTON TO UN-FEATHER POSITION – MONITOR TO SEE THAT PROP-ELLER HAS STOPPED ROTATING	16	7	0	1	0	20	PROP AC PD
7.1.8.5	– IF REQUIRED, REPOSITION PROP-ELLER TO MINIMIZE BUFFET – DEPRESSED PRESSURE CUTOUT OVERRIDE SWITCH – PUSH FEATHER BUTTON UNTIL BLADES ARE NOT IN LINE WITH THE WING (NOT PARALLEL) – MONITOR PROPELLER POSITION	7	11	5	4	11	8	PROP AC PD
7.1.9.1	– COMPLETE THE RESTART CHECKLIST – MAINTAIN AIRSPEED FROM 170 TO 210 KNOTS – ENSURE ENGINEER COMPLETES RESTART CHECKLIST	16	7	0	12	8	3	FLT CONT FLT INST COMM PM AC PD
7.1.9.2	– RECEIVE ENGINEER'S BRIEF	8	12	3	9	10	4	COMM CD
7.1.9.3	– CALL OUT BLADE ANGLE AND ROTATION	12	10	1	10	10	3	COMM CD

Figure 2.2-1: Typical Detailed Task Worksheet

In addition to the subtask, frequency, and criticality data, information as to the subsystem with which each subtask was performed and the general generic task category were included on the task list worksheets. The use of the subsystem and generic task data is explained in Section 2.2.5 of this report.

2.2.4 Rating Process

The next subtask in the total crew station design analysis procedure was to rate each of the crew tasks in order to evaluate and select those most amenable to AST application. After consideration of the variables that affect the application of voice technology to crew station design, a four factor rating system was developed. The four factors are listed and described below.

2.2.4.1 Technical Feasibility Factor.

Could be implemented:

a. Immediately; i.e., requires an isolated word device, limited vocabulary, rigid syntax, speaker training (rating = 1).

b. In two (or more) years; i.e., requires limited continuous speech recognition, syntactic handler, speaker adaptation with little training, limited vocabulary (rating = 2).

c. In four (or more) years; i.e., requires continuous free speech recognition, unconstrained vocabulary, independent speaker (rating = 3).

d. Probably never; cannot be performed effectively by speech, requires 100 percent accuracy in real time (rating = 4).

2.2.4.2 Utility Factor.

a. Voice benefits the crew member; i.e., crew task is amid heavy workload, hand, eyes, or attention used for concurrent tasks, visual channel is overloaded (rating = 1).

b. Voice application is equivalent to present system; i.e., no obvious advantage for applying speech considering workload, time demands, etc. (rating = 2).

c. Voice application creates a disadvantage; i.e., task environment is noise, task is highly critical, voice already is used for other tasks demanding 100 percent accuracy with no time for feedback (rating = 3).

2.2.4.3 Time/Accuracy Requirements Factor.

a. Low requirements; i.e., 80 percent recognition accuracy is sufficient on first attempt with enough time for verification/correction process (rating = 1).

b. Requirements; i.e., 90 percent accuracy with moderate time pressure (rating = 2).

c. High requirements; i.e., 98 percent accuracy required with virtually no time for error recovery (rating = 3).

2.2.4.4 Unassessed Variables Factor. The unassessed variables include aircraft noise, job pressure, cross conversation, lengthy mission segments, etc.

a. None (rating = 1)
b. Few (rating = 2)
c. Some (rating = 3)
d. Many (rating = 4)

2.2.4.5 Rating Assignment Procedure. Using the preceding rating structure, each task was reviewed utilizing the four dimensional factors (i.e., technical feasibility, utility, time/accuracy requirements, and likelihood of unknowns). Thus, each task was assigned a four digit code of numbers corresponding to task factors or requirements. For example, a TACCO tray switching task might be given a 1 2 2 1 code, indicating that it can be implemented now by voice with no real gain over the button push, with little pressure, and with no unforeseen variables.

Overall tasks were assigned four digit codes, and the four digit code was reduced to a one digit code (1-5) corresponding to AST pay-off at this time. The five codes were as follows:

a. **High pay-off (codes of 1111 or 1112) = (Code 1).**

b. Some pay-off (Codes of 2122, 2112, or 2111) = (Code 2).

c. Questionable pay-off (Codes 2222, 1211, 2232, 1221, 1212 or 2233) = (Code 3).

d. Very low pay-off (Codes 3233 or 2222) = (Code 4).

e. No pay-off (Codes 4333, 4334) = (Code 5).

When each task was given a single-digit AST rating, the criticality and frequency ratings from the Courseware documents were applied to the AST rating to arrive at an overall AST rating. The following guidelines were applied to determine the overall AST rating:

a. If criticality is high, frequency is high or moderate, and AST is moderate (Code 2 or 3), then decrease the overall AST rating by one digit.

b. If criticality is moderate, frequency is high or moderate, and AST is moderate (Code 2 or 3), increase the AST rating by one digit.

c. If other situations exist, then set the overall AST rating at a level equivalent to the initial AST rating.

For the purpose of providing summary presentation material and drawing general conclusions as to types of AST application payoff areas, all tasks were converted to a matrix format described in Section 2.2.5 (i.e., placed into generic task by subsystem cells). The AST codes for all tasks within a matrix cell then were treated statistically to determine a single AST code (median) for each matrix cell which reflected the central tendency of that cell. Using standard rounding procedures, the median cell AST rating was converted to a code as follows:

a. AST rating 1.2-1.4 = 1

b. AST rating 1.5-2.4 = 2

c. AST rating 2.5-3.4 = 3

d. All else = Blank, or "C" to indicate relative continuous use by crewmen

In terms of a plan for voice application, a "1" would represent immediate application with good pay-off; a "2" would indicate near-term application with some pay-off, and a "3" would indicate long-term application with questionable pay-off. The "C", for continuous use, indicates that the particular subsystem-generic task cell combination is used relatively continuously, but on a routine and low priority basis. These crew tasks tend to be monitoring functions performed on a routine station keeping basis.

The use of the lower ratings (i.e., 2 and 3) does not necessarily mean that the particular task does not have high potential payoff. The lower rating may mean that the task is a candidate for 6.1 or 6.2 program funding in order to solve a problem of continuous speech recognition, speaker adaptation, or large vocabularies. In order to give visibility to certain tasks which received low ratings only from the technical feasibility factor, they are presented in a special separate pilot matrix (Table 2.2-9) in the following 2.2.5 section (Matrices Development). This section contains matrices for each crew position to show general areas of AST potential payoff in relation to generic crew tasks and subsystems.

2.2.4.6 Rating Assumptions. This entire rating process was based on the following assumptions:

a. Crew members can be trained to use speech input for up to six consecutive hours while maintaing reasonable accuracy.

b. The AST system operates in real-time.

c. Cost is not considered as a factor, at this time; that is, revision of displays and computer programs is allowable.

d. Users are cooperative and resources are committed to ensuring user acceptance through task and system design.

2.2.5 Matrices Development

As previously indicated in Section 1.3, preliminary crew station design data were presented at the July 5 and 6 Apportionment Review. A summary of the crew station task analysis was presented in the form of a matrix for the two crew stations examined (Pilot and TACCO). Because of their summary form, no information as to specific AST application projects could be obtained from these matrices. However, the matrices did point to general areas as to types of generic crew tasks and P-3C subsystems which would tend to be amenable to AST applications. Following the Apportionment Review, crew station design summary matrices were developed for the other crew stations and reworked (with the addition of newer task analysis data) for the first two crewmen.

The first steps in the development of the AST pay-off area matrices were to decide both the level of crew tasks and method of aircraft subsystem allocation. The longer the lists of crew task categories and subsystem categories, the more detailed the information that could be obtained from the cell intersection between these two parameters. However, it was not the intent of these matrices to provide detailed information as to specific AST pay-off areas. Specific applications could come only from detailed analysis of crew procedures and equipment functions. Since the matrices were intended only for overview information, it was decided to provide sufficient task and subsystem comparison data for a one page matrix form. This meant that the crew tasks should be divided into eleven generic categories and the subsystems into thirteen categories with the ASW subsystem divided into ten subcategories. This subcategory division was due to the desirability for relatively more visibility to this subsystem because of its extensive use by all crew members. The following Table, 2.2-1, lists each of the selected generic task categories, along with a brief definition of the particular generic task. Table 2.2-2 is a list of P-3C subsystems and subsystem descriptions taken from the NATOPS manuals. In anticipation of the matrices construction, each crew task was analyzed and categorized as to the type(s) of generic task(s) and subsystem(s) involved in the task accomplishment. These data were indicated by their abbreviations (which are in parenthesis) on the task analysis worksheet form

Table 2.2-1 Generic Task Definitions

	GENERIC TASK:	DEFINITION
1.	MONITOR INDICATOR: (MI)	Observe discrete indicator lights (sound) or quantitative scalar data
2.	MONITOR SITUATION: (MS)	Observe graphical display of situation or tactical data
3.	PERCEIVE DATA: (PD)	Directly observe actual events
4.	FORMULATE PLAN: (FP)	Analyze and/or create a tactic, method, or procedure to follow
5.	DETERMINE SOLUTION: (DS)	Calculate and/or determine (select) the answer to a specific problem
6.	ENTER DATA: (ED)	Perform approximately simultaneous input of several items of data to a data storage or communication system or tape recorder
7.	RECEIVE DATA: (RD)	Observe either a hard copy or display of a large quantity of tabular data
8.	COORDINATE DATA: (CD)	Verbal communication with personnel
9.	ACTIVATE CONTROLS: (AC)	Press, push, enable, or switch a discrete control device
10.	ADJUST CONTROLS: (AC)	Twist, trim, or tune a continuous control device
11.	PERFORM MANEUVER: (PM)	Continuous operation of a complex control system in response to a combination of observed data/events

Table 2.2-2: P-3C Subsystem Definitions

	SUBSYSTEM:	DEFINITION/EQUIPMENT
1.	Propulsion (P)	T56 power plant, engine oil, propeller, fuel control, water injection, APU
2.	Fuel (F)	Tanks, dump system, instruments, pumps
3.	Electrical (E)	Bus distribution, C/B panels, control, generators, inverter, battery, lighting
4.	Hydraulic (HYD)	Pump, reservoirs, accummulator, valves
5.	Environmental Control (EC)	Oxygen, air conditioning, pressurization, anti-icing
6.	Air Frame (AF)	Landing gear, wheels, brakes
7.	Flight Controls (FC)	Boosters, flaps, ailerons, elevators, rudder, control wheels, pedals, trim, AFCS
8.	Flight Instruments (FI)	Airspeed indicator, altimeter, turn and bank indicator, rate of climb, etc.
9.	Communications (COMM)	HF, UHF, VHF, IFF transponder, interphone (ICS)
10.	Navigation (NAV)	Tacan, radio compass, RAWS, Loran, INS, VOR
11.	ECM	Electronic Counter Measures (AN/ALQ-78)
12.	ASW	
	- Search Stores (SS)	- Smoke marker, parachute flair, bathythermograph, sonobuoys, marine marker, DIFAR, AN/AWH-4 Recorder, SB Receiver System
	- On Top Pos Ind (OTPI)	- Group enables aircraft to home on a selected SONO (VHF receiver and UHF direction finder)
	- BY & Sea Noise (BT &SN)	- Bathythermograph sonobuoys, chart recorder
	- MAD	- Magnetic Anomaly Detection: magnetic detecting set, submarine anomaly detecting group, magnetic compensator group, etc.

Table 2.2-2: P-3C Subsystem Definitions (cont.)

SUBSYSTEM:	DEFINITION/EQUIPMENT
- LLLTV (L^3TV)	- Low Light Level TV: TV camera and controls
- Photographic (P)	- Two cameras and controls
- CASS	- Command Active Sonobuoy System: generator control, reference signal generator, and command transmitter, SONO, and recorders
- Data Handling and Display (DH)	- Computer, time code generator, I/O devices, TTY and high speed printer, terminal, signal converters, and displays
- Search Radar (SR)	- AN/APS-115: long and short pulse radar transmitter/receivers, antennas and control
- Armament (A)	- Bombs, torpedoes, mines, rockets, bull pup
13. Crew (C)	Pilot/Copilot, Nav/Comm, Flt Engineer, TACCO, Sensors, 1 and 2, Sensor 3, Technician, Ordnanceman

(reference Figure 2.2-1). After the tasks were rated, they were summarized along with the generic task and subsystem relationships for incorporation into the matrices presented in Tables 2.2-3 through 2.2-7. Table 2.2-8 is a composite for all of the crew positions of all the data. The composite table does not include the continuous use code.

Because there was some concern that the use of the feasibility factor to rate potential payoff areas might mask the choice of research projects, a second pilot matrix was constructed without the feasibility factor. Table 2.2-9 is this matrix. Comparison of this table with Table 2.3-3, which included the use of the feasibility factor, shows several differences. The additions to Table 2.2-9 are as follows:

a. One high payoff area is added to the Monitor Indicator row under Flight Instruments. This row suggested a project for a pilot cue/alert system.

b. Two high payoff areas were added to the Determine Solution row under Fuel and Crew.

c. The low payoff rating for the Receive Data row under Communications changed to a high payoff rating. These data along with the previous data suggested a voice data retrieval system.

d. Most of the low and medium payoff areas for the Activate Controls row changed to high payoff areas. These areas suggest both the need for a checklist verification system and a pilot VIS, in general.

e. The Adjust Controls row payoff area under Communications is changed from medium to high, and the low payoff area for the Perform Maneuver row under Flight Instruments is added.

Although the construction of these matrices was helpful in selecting candidate applications/projects to be presented in the Program Plan, the total process of generating the data to go into the matrices proved to be even more helpful. The following section describes alternative methodologies for determining and identifying crew station design AST applications/projects.

Table 2.2-3: Crew Station Design Voice Technology Potential Payoff Areas

POSITION: **P-3C PILOT**

MISSION SEGMENT: **ON STATION**

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPULSION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW:	SEARCH STORES	ON-TOP POS. IND.	BT & SEA NOISE	MAD	LLLTV	PHOTOGRAPHIC	CASS	DATA HANDLING & DISPLAY	SEARCH RADAR	ARMAMENT	CREW
MONITOR INDICATOR	1	2	C	C	C		C	C	1								2				2		
MONITOR SITUATION																			C				
PERCEIVE DATA																							C
FORMULATE PLAN																							
DETERMINE SOLUTION																							
ENTER DATA																							
RECEIVE DATA									3										3				
COORDINATE DATA									C														C
ACTIVATE CONTROLS	3								2	3			2				2		3		2		
ADJUST CONTROLS									2										3		3		
PERFORM MANEUVER							C																

Table 2.2-4: Crew Station Design Voice Technology Potential Payoff Areas

POSITION: P-3C TACCO

MISSION SEGMENT: ON STATION

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPUSLION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW: SEARCH STORES	ON-TOP POS. IND.	BT & SEA NOISE	MAD	LLLTV	PHOTOGRAPHIC	CASS	DATA HANDLING & DISPLAY	SEARCH RADAR	ARMAMENT	CREW
MONITOR INDICATOR																		C				
MONITOR SITUATION																		C				
PERCEIVE DATA																						C
FORMULATE PLAN																						
DETERMINE SOLUTION																						
ENTER DATA																		2				
RECEIVE DATA																		3				
COORDINATE DATA									3													C
ACTIVATE CONTROLS									C									1				
ADJUST CONTROLS																		2				
PERFORM MANEUVER																						

Table 2.2-5: Crew Station Design Voice Technology Potential Payoff Areas

POSITION: P-3C NAV/COMM

MISSION SEGMENT: ON STATION

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPULSION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW:	SEARCH STORES	ON-TOP POS. IND.	BT & SEA NOISE	MAD	LLLTV	PHOTOGRAPHIC	CASS	DATA HANDLING & DISPLAY	SEARCH RADAR	ARMAMENT	CREW
MONITOR INDICATOR									3	3									3				
MONITOR SITUATION																							
PERCEIVE DATA									3	3													
FORMULATE PLAN																							
DETERMINE SOLUTION																							
ENTER DATA									3	3									2				
RECEIVE DATA									C										C				
COORDINATE DATA									C														C
ACTIVATE CONTROLS									C										2				
ADJUST CONTROLS									C														
PERFORM MANEUVER																							

Table 2.2-6: Cres Station Design Voice Technology Potential Payoff Areas

POSITION: P-3C SENSO 1 & 2

MISSION SEGMENT: ON STATION

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPULSION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW: SEARCH STORES	ON-TOP POS. IND.	BT & SEA NOISE	MAD	LLLTV	PHOTOGRAPHIC	CASS	DATA HANDLING & DISPLAY	SEARCH RADAR	ARMAMENT	CREW
MONITOR INDICATOR												2		2			2	2				
MONITOR SITUATION																		C				
PERCEIVE DATA																						
FORMULATE PLAN																						
DETERMINE SOLUTION																		1				
ENTER DATA																		1				
RECEIVE DATA									3									C				
COORDINATE DATA									3													3
ACTIVATE CONTROLS									C									1				
ADJUST CONTROLS																		3				
PERFORM MANEUVER																						

Table 2.2-7: Crew Station Design Voice Technology Potential Payoff Areas

POSITION: P-3C SENSO 3

MISSION SEGMENT: ON STATION

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPUSLION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW:	SEARCH STORES	ON-TOP POS. IND.	BT & SEA NOISE	MAD	LLLTV	PHOTOGRAPHIC	CASS	DATA HANDLING & DISPLAY	SEARCH RADAR	ARMAMENT	CREW
MONITOR INDICATOR																2			2	2			
MONITOR SITUATION																			C				
PERCEIVE DATA																							
FORMULATE PLAN																							
DETERMINE SOLUTION																							
ENTER DATA																2			2				
RECEIVE DATA																							
COORDINATE DATA									2														3
ACTIVATE CONTROLS									C										2	3			
ADJUST CONTROLS																							
PERFORM MANEUVER																							

Table 2.2-8: Crew Station Design Voice Technology Potential Payoff Areas

POSITION: <u>COMPOSITE</u>

MISSION SEGMENT: <u>ON STATION</u>

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPUSLION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW: SEARCH STORES	ASW: ON-TOP POS. IND.	ASW: BT & SEA NOISE	ASW: MAD	ASW: LLLTV	ASW: PHOTOGRAPHIC	ASW: CASS	ASW: DATA HANDLING & DISPLAY	ASW: SEARCH RADAR	ASW: ARMAMENT	ASW: CREW
MONITOR INDICATOR	1	2							2	3					2		2		2	2	2	
MONITOR SITUATION																						
PERCEIVE DATA																						
FORMULATE PLAN																						
DETERMINE SOLUTION																						
ENTER DATA									3	3					2				2			
RECEIVE DATA									3										3			
COORDINATE DATA									3													
ACTIVATE CONTROLS	3								2	3		2					2		2		2	
ADJUST CONTROLS									2										3		3	
PERFORM MANEUVER																						

Table 2.2-9: Crew Station Design Voice Technology Potential Payoff Areas
(Excluding Feasibility Rating Factor)

POSITION: P-3C PILOT

MISSION SEGMENT: ON STATION

POTENTIAL PAYOFF CODE:

1. HIGH
2. MEDIUM
3. LOW

SUBSYSTEMS

GENERIC TASKS	PROPULSION	FUEL	ELECTRICAL	HYDRAULIC	ECS	AIR FRAME	FLT CONTROLS	FLT INSTRUMENTS	COMMUNICATIONS	NAVIGATION	ECM	ASW: SEARCH STORES	ON-TOP POS. IND.	BT & SEA NOISE	MAD	LLLTV	PHOTOGRAPHIC	CASS	DATA HANDLING & DISPLAY	SEARCH RADAR	ARMAMENT	CREW
MONITOR INDICATOR	1	2	C	C	C		C	1	1								2				2	
MONITOR SITUATION																			C			
PERCEIVE DATA																						C
FORMULATE PLAN																						
DETERMINE SOLUTION		1																				1
ENTER DATA																						
RECEIVE DATA									1										3			
COORDINATE DATA									C													C
ACTIVATE CONTROLS	1							1	1	3		2					1		1		1	
ADJUST CONTROLS									1										3		3	
PERFORM MANEUVER							C	3														

2.2.6 Alternative Applications/Projects Identification Methodologies

Rather than determine applications/projects from crew task analysis, the hardware used in the accomplishment of crew procedures could be examined directly. Certain displays and controls tend to imply the possible additional use or replacement use of AST devices for specific tasks. For example, cockpit annunciator lights imply the use of voice generated advisory data. Multifunction discrete switches may be effectively replaced by automatic speech recognition equipment. The use of paper and pencil for procedural logging of discrete written words or phrases implies the use of automatic speech recognition. Another approach would be to examine crew tasks to determine all of those which require a high frequency of combined hand and eye use. AST could be used to relieve much of the hand task loading and its use should therefore be investigated as an applications/project. Several potential applications/projects which may be categorized crew station design related were suggested by the task analysis process directly before building the generic task/subsystem matrix. Several crew station design applications/projects were also suggested from the technology review process (Reference Section 2.1).

2.3 Significant Additional Application Areas

Prior to the initiation of work on this study program, it was anticipated that all the proposed applications/projects could be derived from (and categorized accordingly) the three areas of crew station design, performance measurement, and training. However, two additional categories are appropriate to add because certain of the proposed applications/projects do not lend themselves to any particular one of the three previously indicated categories. The two additional categories are research and development and maintenance. The research and development category pertains to those projects which would be related equally to each of the other categories and would generally be required to preceed the conduct of other projects. The maintenance category was provided for one project which pertains to both crew station design and training. The following sections present general information on the performance measurement and training aspects of AST.

2.3.1 Performance Measurement

The application of speech technology has significant implications in the area of operator performance measurement. A basic tenet of quantitative measurement schemes is that any activity which can be objectively observed can also be measured. The use of speech technology can serve to increase the number and types of measurable responses which until now have not been easily observable events. The utility of speech technology may have a significant impact on performance measurement capabilities by expanding the measurement domain to include variables and parameter sets not previously available for observation in any precise manner.

In order to determine specific possible AST performance measurement projects, the crew station analysis task was reexamined. In addition to being examined for basic performance measurement applications, these tasks were examined in terms of characteristics such as possible performance measurement parameters and conditions and the applications project evaluation methodology.

The evaluation for the above performance measurement characteristics has wider application than just to proposed performance measurement projects. The end product of this study program was a plan which contains detailed methodology as to what AST projects should be developed in the areas of performance measurement, crew station design, and training. Crew station design and training applications needed to be examined in terms of what performance measurement data could be provided by their test and evaluation. Figure 2.3-1 illustrates the anticipated performance measurement data available for each of the projects/applications.

2.3.2 Training

The application of AST to different areas of training, particularly synthetic training with simulators and cockpit procedures trainers, can facilitate the cost effectiveness of present training. The increased cost effectiveness can be accomplished by:

MEASUREMENT CONDITIONS AND PARAMETERS

WITHOUT AST

SELECTED P-3C
CREW TASKS

MONITOR INDICATOR
ENTER DATA
RECEIVE DATA
ACTIVATE CONTROLS
ADJUST CONTROLS
COORDINATE DATA

- RESPONSE TIME
- COORDINATION ERRORS
- PROCEDURE ERRORS
- CORRECTED ERRORS (ERASE)

WITH AST

SAME CREW TASKS

- RESPONSE TIME
- ONLY ERRORS IN SPEECH
- ERRORS IN AST PROCEDURES
- ERRORS IN ALL PROCEDURES, AST & AC

- IMPROVEMENT
- NO CHANGE
- DEGRADED

COMBINED

AST USED IN PARALLEL TO EXISTING SYSTEM FOR SELECTED PREVIOUS TASKS

Figure 2.3-1, Anticipated Performance Measurement Data

a. reducing training manning,

b. facilitating the roles of training personnel by automating instructor functions,

c. providing training where it is/has been difficult to schedule training before because of crew availability or skill level, and

d. providing for objective measurement of training and transfer of training.

To derive specific applications of AST in the area of training, team training environments (such as that for the P-3C) were considered. This coincides with th Fleet Readiness Squadron (FRS, formerly called RAG) level of training. Projects were identified that address long standing problems in team training.

2.4 Applications Assessment

The accomplishment of the preceding analysis study tasks (crew station design, performance measurement, and training) resulted in five separate categories or lists of possible AST applications/projects which might be pursued in accordance with the recommendations provided in the Program Plan. Table 2.4-1 lists each of these possible projects divided according to the AST category from which they were derived. As can be seen from the table, the majority of the proposed projects were in the area of crew station design. Rather than propose all of these projects/activities for eventual investigation or development, it was deciced at the program kickoff meeting to include a project assessment portion of the total task effort. Each of the activities/projects was compared on the basis of certain characteristics. They were numerically rated and rank ordered to determine the most promising activities/projects for incorporation into the Program Plan. The following sections describe the details of this assessment process.

2.4.1 Assessment Factors

The characteristics chosen to evaluate the activities/projects were impact, risk, and cost. The first two were somewhat similar to two of the factors

Table 2.4-1, Proposed AST Applications/Projects

CREW STATION DESIGN
User Studies
Vocabulary Development
Development of a Syntactic Handler
Ruggedization of ASR Equipment
Empirical Comparison of SENSO 1 & 2 Station
Empirical Comparison of Pilot Station
Empirical Comparison of TACCO Station
Microphone Use
Speech Recognition Equipment Multiplexing
Voice Generation Personality Development
Automated Voice Data Retrieval System
Flight Instrument Information System
Checklist Prompts - Procedures Monitoring
AST Design Criteria Development
PERFORMANCE MEASUREMENT
Aircraft Evaluation Aids
Workoad Monitoring
Stress Monitoring Feasibility
Procedures Monitoring
Workload Optimized Display Systems
TRAINING
Simulated Crew Member
Replacement of Device Operator
Demonstration of the Transfer of Training
Automated Cockpit Familiarity Training
RESEARCH AND DEVELOPMENT
Continuous Speech Recognition
Speaker Independence
User Acceptance Studies
Feature Extractor Control
Voice Recognition Feedback
MAINTENANCE
Cockpit Maintenance Support

used to rate the crew station design tasks (Reference Section 2.2.4).

a. The impact characteristic includes the factor of practicality or probable utility. It was rated on the basis of estimated advantage to future users. The projects receiving the best ratings (lowest numerical value) in this characteristic category are the ones that are the easiest to justify in the program plan.

b. Risk, or risk of project success, includes such factors as ASR required time delay, accuracy rates, and maximum background noise allowable. Unassigned variables such as availability of resources, use of known methods, user acceptance, probable system interface, probable mission duration/fatigue, and required crew intercom use are also included in the risk evaluation characteristic.

c. The cost characteristic is based upon estimates as to the probable availability of facilities, equipment, personnel, development costs and time required to evaluate the activities/projects.

2.4.2 Trade-Off Matrix

Each of the activities/projects has been listed in the Table 2.4-2 matrix along with the three evaluation characteristics. Each activity/project was evaluated with a five point rating system on the basis of how well it met each evaluation criteria when compared to the other projects. The projects that were evaluated as having the greatest impact, most probability of success, and/or least cost, received the best ratings (score or value of 1). Conversely, the projects which seemed to have the least utility, success, and/or most cost, received the worst ratings (fives). Each project was rated in comparison to each characteristic by three project persons and the assigned ratings were then totaled.

It should be noted that no evaluation has been assigned to the factor of present feasibility. It was felt that this characteristic should be dealt with by scheduling and recommended assignment of research and development funds according to the program acquisition cycle categories of 6.1, 6.2, and 6.3.

Table 2.4-2, Trade-off Matrix

Project	Impact Factor $I=I_1+I_2+I_3$	Risk Factor $R=R_1+R_2+R_3$	Cost Factor $C=C_1+C_2+C_3$	Total Evaluation $T=3I+R+C$
User Voice Studies	7	5	6	32
Vocabulary Development	8	3	3	30
Devel. of a Syntactic Handler	7	5	3	29
Ruggedization of ASR Equip.	5	4	9	28
Empirical SENSO 1-2 Sta. Comp.	5	9	12	36
Empirical Pilot Sta. Comp.	6	9	12	39
Empirical TACCO Sta. Comp.	6	11	12	41
Throat Microphone Use	7	5	4	30
ASR Equip. Multiplexing	11	6	7	46
Voice Gen. Personality Devel.	11	5	4	42
Voice Data Retrieval	7	5	6	32
Flight Instr. Info. Sys.	5	7	8	30
Checklist Prompts-Procedures	4	6	10	28
AST Design Crit. Dev.	8	6	3	33
Aircraft Eval. Aids	11	8	9	50
Workload Monitoring	9	9	10	46
Stress Monitoring Feasibility	12	5	3	44
Procedures Monitoring	8	9	7	40
Workload Optimized Display	11	12	9	54
Simulated Crew Member	4	7	9	28
Replace Trn. Device Oper.	8	6	6	36
Training Transfer Demo.	10	9	5	44
Auto Cockpit Fam Training	8	6	9	39
Continuous Speech Recog.	3	12	15	36
Speaker Independence	4	10	6	28
User Acceptance Studies	6	5	3	26
Feature Extractor Control	13	12	9	60
Cockpit Maintenance Support	11	7	6	46
Voice Recognition Feedback	9	6	5	38

The following describes the factor rating values.

a. IMPACT (I_n)

Range - 1 - Best or most potential benefit
5 - Worst or least potential benefit

b. RISK (R_n)

Range - 1 - Best or least chance of failure
5 - Worst or most chance of failure

c. COST (C_n) Total project expenditures using 1978 dollars.

Range - 1 - 50K to 100K
2 - 100K to 250K
3 - 250K to 500K
4 - 500K to 1000K
5 - 1000K to 5000K

d. TOTAL EVALUATION FACTOR (T) A factor used to rank the various projects in terms of relative desirability. Impact has been weighted by a factor of 3 to emphasize its importance over cost and risk. The lower the value of "T" the more attractive it is with respect to its implementation.

Range - T = 26 - Best
T = 54 - Worst

Because three project persons contributed ratings to each evaluation factor, the individual ratings were summed for each factor. Then a total evaluation value, T, was calculated by simply adding three times the total impact factor plus the total risk and cost factors. The total evaluation value (T) was used to rank the 29 projects. Using a subjective criterion of 50 T points, three projects were deleted, reducing the total recommended projects to 26.

The Prioritized Project List is shown in Table 2.4-3 and shows the projects ranked in order of their Total Evaluation Factor (T). Also included in this table is the potential sponsoring/monitoring agency, the cost factor (C) where

Table 2.4-3, Prioritized Project List

Number	Total Eval. Score	Project	Agency	Cost Factor	Duration (Months)
1	26	User Acceptance Studies	ONR	3	4
2	28	Ruggedization of ASR Equip.	NADC	9	12
3	28	Checklist Prompts-Procedures	NADC	10	24
4	28	Speaker Independence	ONR/NTEC	6	12
5	28	Simulated Crew Member	NTEC	9	30
6	29	Devel. of a Syntactic Handler	NADC	3	12
7	30	Vocabulary Development	ONR/NADC	3	8
8	30	Microphone Use	NADC	4	3
9	30	Flight Instr. Info. Sys.	NADC	8	24
10	32	User Voice Studies	ONR	6	24
11	32	Voice Data Retrieval	NADC	6	18
12	33	AST Design Criteria Dev.	NADC	3	12
13	36	Continuous Speech Recog.	ONR	15	[illegible]
14	36	Replace Trn. Device Oper.	NTEC	6	12
15	36	Empirical SENSO 1-2 Sta. Comp.	NADC	12	42
16	38	Voice Recognition Feedback	ONR/NADC	5	12
17	39	Auto Cockpit Fam Training	NTEC	9	24
18	39	Empirical Pilot Sta. Comp.	NADC	12	36
19	40	Procedures Monitoring	NADC	7	24
20	41	Empirical TACCO Sta. Comp.	NADC	12	36
21	42	Voice Gen. Personality Devel.	ONR	4	6
22	44	Stress Monitoring Feasibility	ONR/NADC	3	6
23	44	Training Transfer Demo.	NTEC	5	12
24	46	Cockpit Maintenance Support	NADC/NTEC	6	12
25	46	Workload Monitoring	NADC	10	24
26	46	ASR Equipment Multiplexing	ONR/NADC	7	24

C is the total of three ratings by separate evaluators, and the estimated project duration in months. Note that the cost factor (C) must be divided by three if it is to be used to correlate to the actual dollar values listed in the cost description.

3.0 CONCLUSIONS

3.1 General Conclusions and Recommendations

The specific conclusions/recommendations of this report are those projects listed in Table 2.4-3 and detailed in the Program Plan. The general conclusions and recommendations are as indicated in the following sections.

3.1.1 Conclusions

a. AST can be beneficially applied to a variety of Navy operational and training programs including:

   1. New generation patrol aircraft design.
   2. Simulators and crew procedures trainers
   3. Operational ground support including maintenance

b. AST application should proceed at a rate warranted by positive empirical results (from proposed programs). Application should be tailored to use the advanteages of AST.

c. AST has better applicability for some crew positions than others.

d. The end result of the 6 year plan will be:

   1. A developed technology ready for application
   2. Guidelines for its application
   3. Immediate improvements in training and performance measurement

3.1.2 Recommendations

a. Implement the Plan as closely as possible.

b. Initiate a follow-up (sequel) to this planning program to investigate the progress of all projects in the plan and revise plans or projects as necessary - Budget $100K.

c. Effect positive coordination between all Navy organizations involved so as to produce the best overall result for the Navy (Fleet Aviation).

3.2 Schedule

As a part of the process of developing the details for accomplishment of the applications/projects a task schedule breakdown was constructed for each. This analysis helped determine the total time required to perform each project. However, much of the purpose of this study contract was to assist Navy planners in

determining just when to perform which tasks. This determination was made after the projects were selected and prioritized. The overall scheduling was based on the following four factors:

a. Certain projects required other projects to precede them and must therefore occur later in the overall schedule.

b. The estimated length of some projects required that they be started relatively early if they were to be completed during the six year total time period.

c. Although not significant, the AST state-of-the-art required for some projects indicated that they could be better accomplished at a later date.

d. In order to equalize the budget loading over the six year period some tasks were shifted to the right on the schedule (delayed).

Consideration of the project sequencing requirements alone, i.e., which projects were dependent on the accomplishment of which other projects, lead to the development of the Figure 3.2-1 Suggested Project Sequencing Chart. This chart is somewhat similar to a system engineering PERT chart. The projects on the left should be accomplished before those on the right side. The arrows indicate the general order of accomplishment.

Figure 3.2-2 is the Integrated AST Projects Schedule. This schedule takes the data from Figure 3.2-1 and adds the factors of project length, AST state-of-the-art, and budget leveling over a six year period from October 1978 to October 1984. The fiscal years are used for budgeting compatibility.

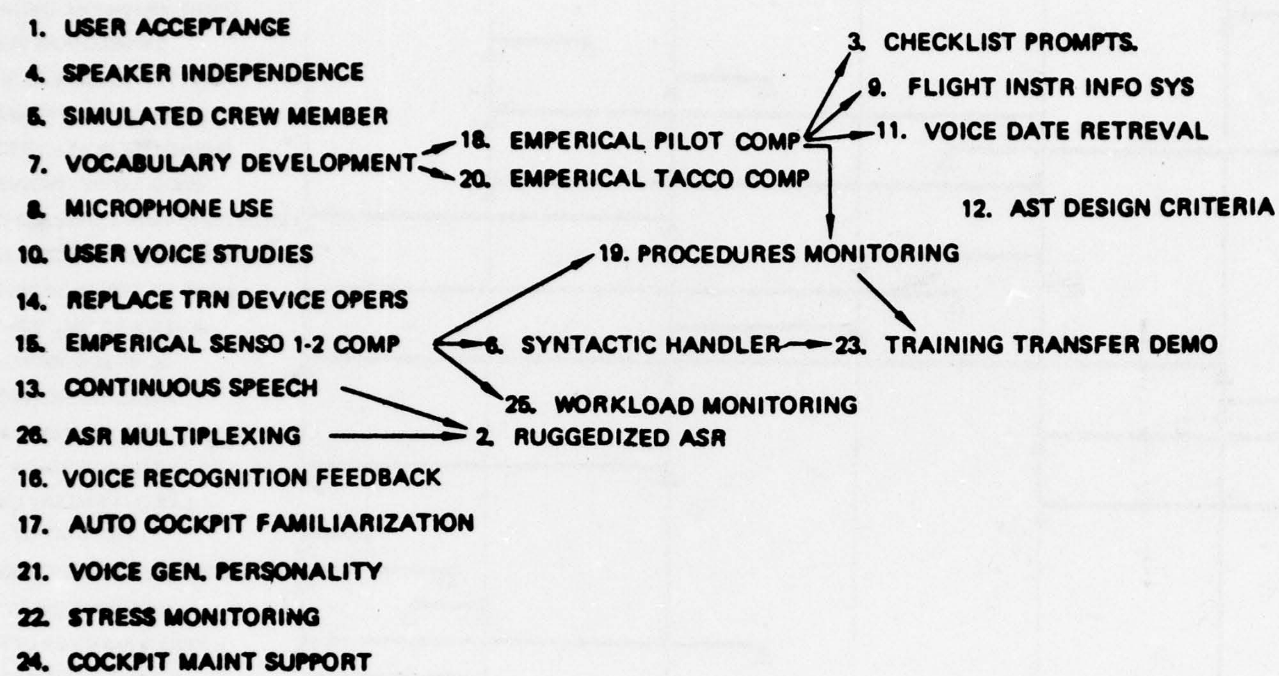

Figure 3.2-1: Suggested Project Sequencing Chart

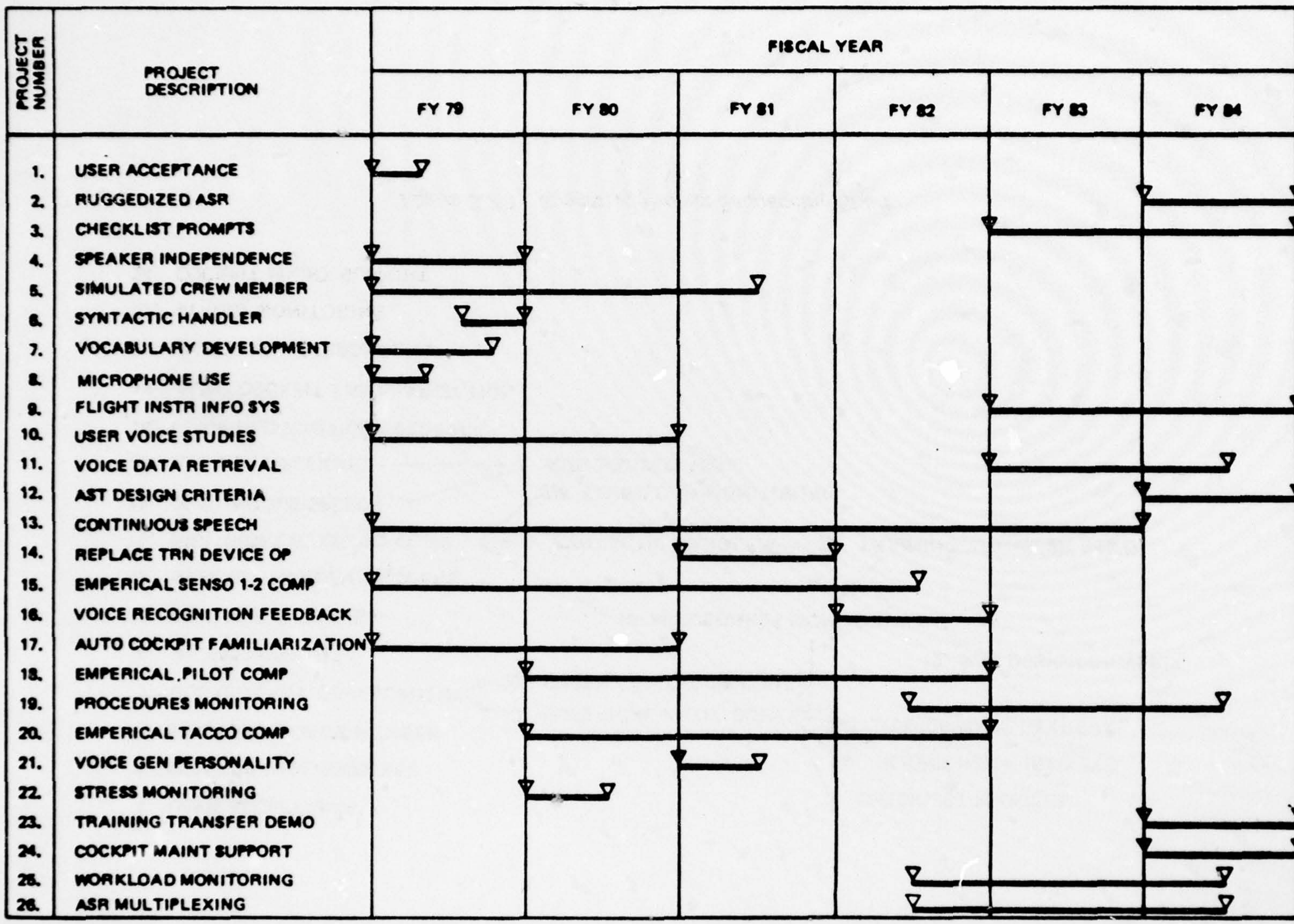

Figure 3.2-2: Integrated AST Projects Schedule

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